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Applicant:	Mascarenhas, Angelo	**Examiner:**	Jerome Jackson, Jr.
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Commissioner for Patents
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I CERTIFY THAT, ON FEBRUARY 19, 2004, THIS PAPER IS BEING DEPOSITED WITH THE U.S. POSTAL SERVICE AS FIRST CLASS MAIL IN AN ENVELOPE ADDRESSED TO THE COMMISSIONER FOR PATENTS, P.O. BOX 1450, WASHINGTON, D.C. 22313-1450.

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DECLARATION OF ANGELO MASCARENHAS, PH.D., UNDER 37 C.F.R. § 1.132

1. I, Angelo Mascarenhas, of 2285 S. Holman, Golden, Colorado 80228, am the inventor of the invention described and claimed in the above-referenced patent application.

2. I am a Principal Scientist at the National Renewable Energy Laboratory in Golden, Colorado, where I have worked in scientific research for the past 16 years in the field of solid state physics and basic sciences relating to semiconductor materials. I have both M.S. and Ph.D. degrees in Physics from the University of Pittsburgh, and I am currently the Principal Scientist and Team Leader for Solid State Spectroscopy at the National Renewable Energy Laboratory. My curriculum vitae is attached hereto as Exhibit 1.

3. I am making this Declaration to provide information to help the examiner in this patent application to understand, *inter alia*, that the photoluminescence and

electroluminescence curves in the Kuznetsov reference do not show, teach, or suggest any lowering of the bandgap of the GaP host lattice by the addition of Bi and N.

4. It is well-known that the bandgap of GaP at 300K (room temperature) is 2.27 eV, and, at 1.6K (very low temperature), the bandgap of GaP is 2.35 eV. Kuznetsov used this low temperature bandgap value of $Eg = 2.350 \pm 0.002$ eV to determine the binding energy of electron-hole pairs at bismuth traps, which is the A^{Bi} line in Kuznetsov Figure 1 at 2.231 eV, i.e., 2.350 eV - 2.231 eV = 0.119 eV or 119 meV (see Kuznetsov, page 417, column 2, last paragraph). Therefore, Kuznetsov Figure 1 shows ***distinct*** radiative recombination ***from isolated Bi*** at the line $A^{Bi} = 2.231$ eV in curve 1 for a temperature of 4.2K and about 2.219 eV in curve 2 for a temperature of 77K, as well as ***distinct*** radiative recombination ***from isolated N*** at the line $A^{N} = 2.316$ eV in curve 1 for 4.2K temperature. As Kuznetsov explains on page 417, column 2, last paragraph, in addition to the distinct zero-phonon A^{N} and A^{Bi} lines of exitons bound to nitrogen and bismuth shown clearly in the spectra of Figure 1, the spectra in Figure 1 also show several of the longitudinal optic (LO) replicas of the zero-phonon A^{N} and A^{Bi} lines, i.e., radiative transitions after having emitted 1 longitudinal optic phonon A-LO, A^1-LO, two phonons A-2LO, A^1-2LO, three phonons A-3LO, A^1-3LO, etc., as well as a NN, nitrogen-pair line and Bi-Si impurity lines and associated LO phonons. Therefore, ***all of the emissions shown in Kuznetsov*** Figure 1 are due to ***distinct*** radiative recombinations from ***isolated Bi, N, NN, and Bi-Si impurities***, and ***none of the emissions in Kuznetsov*** Figure 1 have anything to do with radiative recombination across the ***bandgap of the GaP*** host lattice.

5. We know from later studies, e.g., Y. Zhang et al., "Effects of heavy nitrogen doping in III-V semiconductors---How well does the conventional wisdom hold for dilute nitrogen 'III-V-N alloys'?", Phys. Stat. Sol. (b) 240, No. 2, 396-403 (2003) [attached hereto as Exhibit 2], that it requires concentrations of N that are orders of magnitude higher than those reported by Kuznetsov to even begin merging the A^N line (distinct emission from N) with the GaP band edge and thereby to shift the GaP band edge downwardly to lower the effective bandgap of the GaP host lattice. For example, Kuznetsov's highest N concentration was only 2 x 10^{18} cm^{-3}, which is about 0.01%, whereas Figure 1 in Y. Zhang et al. [Exhibit 2] shows much higher N concentrations of 0.35%, 0.42%, 0.56%, and 0.91%, the higher of which begin to show merging of the nitrogen A-line with the GaP band edge. ***No such merging is shown in Kuznetsov***. The N and Bi impurity concentrations discussed in Kuznetsov are orders of magnitude too low for there to be any merging of distinct N and distinct Bi radiative recombination levels with the bandgap of the GaP, so there is no lowering of the effective bandgap of GaP by the N and Bi in Kuznetsov.

6. The much earlier article, D. G. Thomas and J. J. Hopfield, "Isoelectronic Traps Due to Nitrogen in Gallium Phosphide", Phys. Rev. 150, No. 2, pages 680-689 (1966), has N concentrations (e.g., 1.2 x 10^{18} cm^{-3}), which are similar to those of Kuznetsov and which also show the similar distinct A-line and NN lines due to radiative recombinations from N and from NN pairs. Like Kuznetsov, the A-line and NN-lines from such lower concentrations of N in GaP used by D. G. Thomas and J. J. Hopfield, *supra*, ***remain distinct*** from the GaP adsorption edge at 2.35 eV---thus no lowering of the GaP bandgap. Further, even with the merging shown by the much higher N

concentrations (0.35% to 0.91%) in Y. Zhang et al. [Exhibit 2], the effective bandgap of the GaP host is not yet lowered to the range of 1.55 eV to 1.93 eV recited in claim 85 of my above-referenced patent application. Therefore, it is just ***not possible*** for the low concentrations of Bi and N used by Kuznetsov ***to have any bandgap lowering effect*** on the GaP, let alone down to the 1.55 eV to 1.93 eV bandgap range of my invention.

7. Kuznetsov reported his observation of a yellow-orange band that peaks at 1.96 eV at 300K (room temperature), which he correctly attributed to radiative recombination from the Bi impurities in his GaP (see Kuznetsov abstract as well as page 417, third paragraph, and Figure 2). However, this yellow-orange Bi emission band, which Kuznetsov observed peaking at 1.96 eV (room temperature), is distinct from, and has no relevance to, the bandgap of the GaP host and should not be confused with it. This distinction is very clear, because Kuznetsov, himself, shows a higher energy peak ($\approx$ 2.2 eV) in his Figures 2 and 3, which he attributes to radiative recombination from isolated N impurities in GaP (see Kuznetsov, page 419, second paragraph), which would not be distinguishable from the Bi peak at 1.96 eV, if the Bi and N impurity levels had merged with the GaP valence and conduction bands to lower the GaP bandgap to that range.

8. Consequently, there is no technical or scientific basis for the examiner's assertion that the limitations in my claim 85 "in a range of about . . . [1.55 eV to] 1.93 eV do not structurally distinguish over Kuznetsov" or that Kuznetsov "teaches similar bandgap."

9. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and

further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

A. Mascarenhas

Angelo Mascarenhas, Ph.D.

Date: 2/12/04